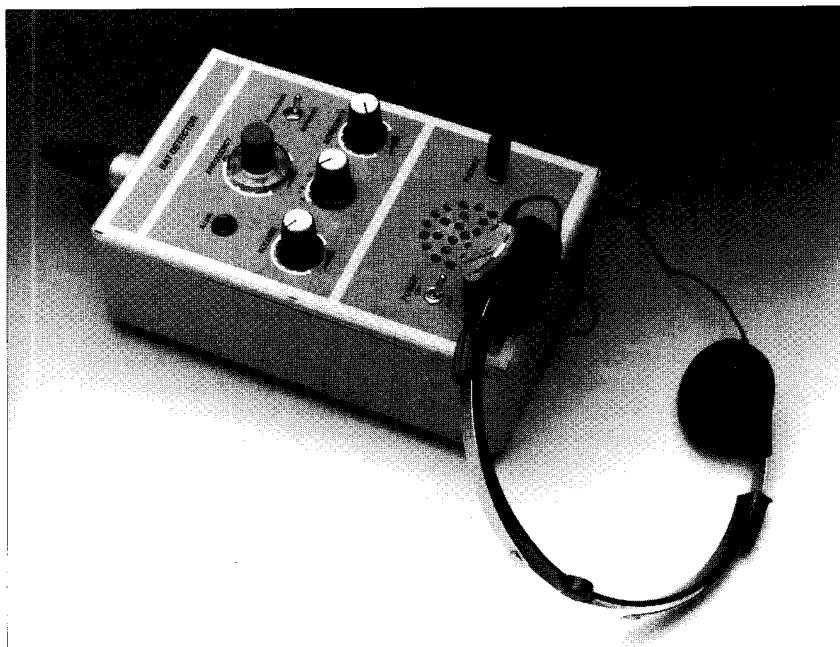


BAT DETECTOR

Design by L. Lemmens



The detector makes sounds at frequencies of 10–300 kHz audible to human beings. The conversion is carried out either by a superheterodyne circuit or a frequency divider. Although it enables listening to bats, and a number of other mammals, as well as insects, the detector is particularly useful for testing ultrasonic alarm equipment.

Human beings can only hear sounds in the frequency range of 20 Hz to 20 kHz and even that depends on age. There are many animals that have a much wider range of hearing: bats, dolphins and whales, for instance, can hear sounds at frequencies up to 200 kHz. The hearing range of man, some mammals and a few insects is given in **Fig. 1**. The vocal range is normally rather narrower: 70–80% of the hearing range.

The ultrasonic sounds made by bats and dolphins are not so much used to communicate (at least not as far as scientists are aware of), but rather as a means of navigation similar to man's radar and sonar systems.

Bats emit short bursts of ultrasonic tones to orient themselves and to locate food in the form of insects. These tones may be of constant frequency (CF) or they may vary in frequency, that is, be frequency modulated (FM). Some species of bat emit an 83 kHz burst of CF tones that are frequency modulated when they die out. Each tone lasts 30–40 ms. Another species emits frequency-modulated pulses that fall in frequency from 60 kHz to 30 kHz in 10 ms. The FM tones are used by all species to determine the distance to

the insect, while the CF tones serve to determine the relative speed with respect to the insect. The echoes returned by the insect also contain information about the speed at which the insect moves its wings; from this, the bat can determine the type and size of insect. The measurements made by the bat depend on two well-known physical phenomena: the Doppler effect and interference.

The Doppler effect is the apparent change of frequency caused by the relative motion of the source of radiation

and the observer. An example is the change in frequency of the sound heard when a train or aircraft is moving towards or away from an observer.

Interference is the interaction between two or more waves of the same frequency emitted by a coherent source. The wavefronts are combined according to the principle of superposition. In the case of the bat, the two waves are the emitted sound and that of the echo, which are combined in the ear of the bat.

Bats are very useful animals that cause no damage, harm no one, and are protected by law. They, and a number of birds, keep the insect population under control. For instance, a single bat consumes no fewer than 60 000 mosquitos during the summer. A bat has to eat a lot during the warmer season, because it loses about 25% of its body weight during hibernation. We should leave these interesting little animals in peace and quiet during their hibernation and also in spring when they are busily feeding and looking after their young family.

Nevertheless, the present detector can be used to study them during spring and summer: most bats can be heard at distances of 20–30 m (65–90 ft). This is not surprising when it is realized that some species emit ultrasonic sounds at a level of 100 dB (which is equivalent to that of a pneumatic hammer).

The divider in the detector enables the entire range of 10–300 kHz to be monitored, but it has the disadvantage of 'losing' the original waveform; only the frequency information is retained. However, the superheterodyne section of the detector leaves the original waveform intact, but can scan the frequency range only in segments 15 kHz wide. Also, the superheterodyne section is more sensitive than the divider.

Circuit description

The electret microphone in the circuit of **Fig. 2** picks up the ultrasonic sounds. It has an integral amplifier, which obtains its power supply via R_1

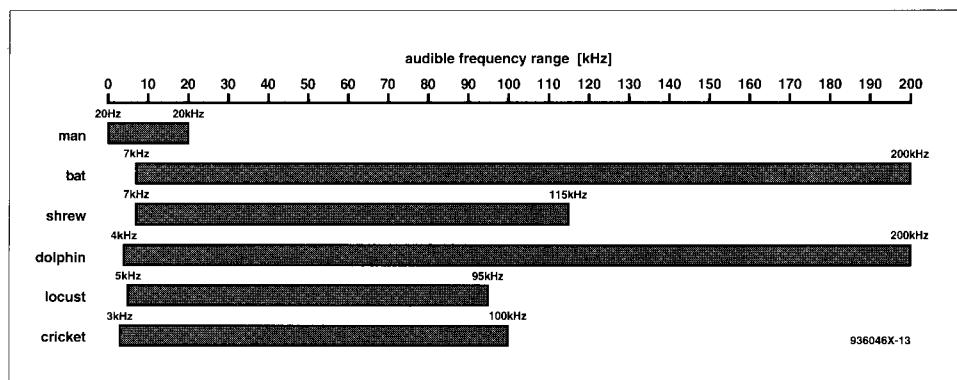
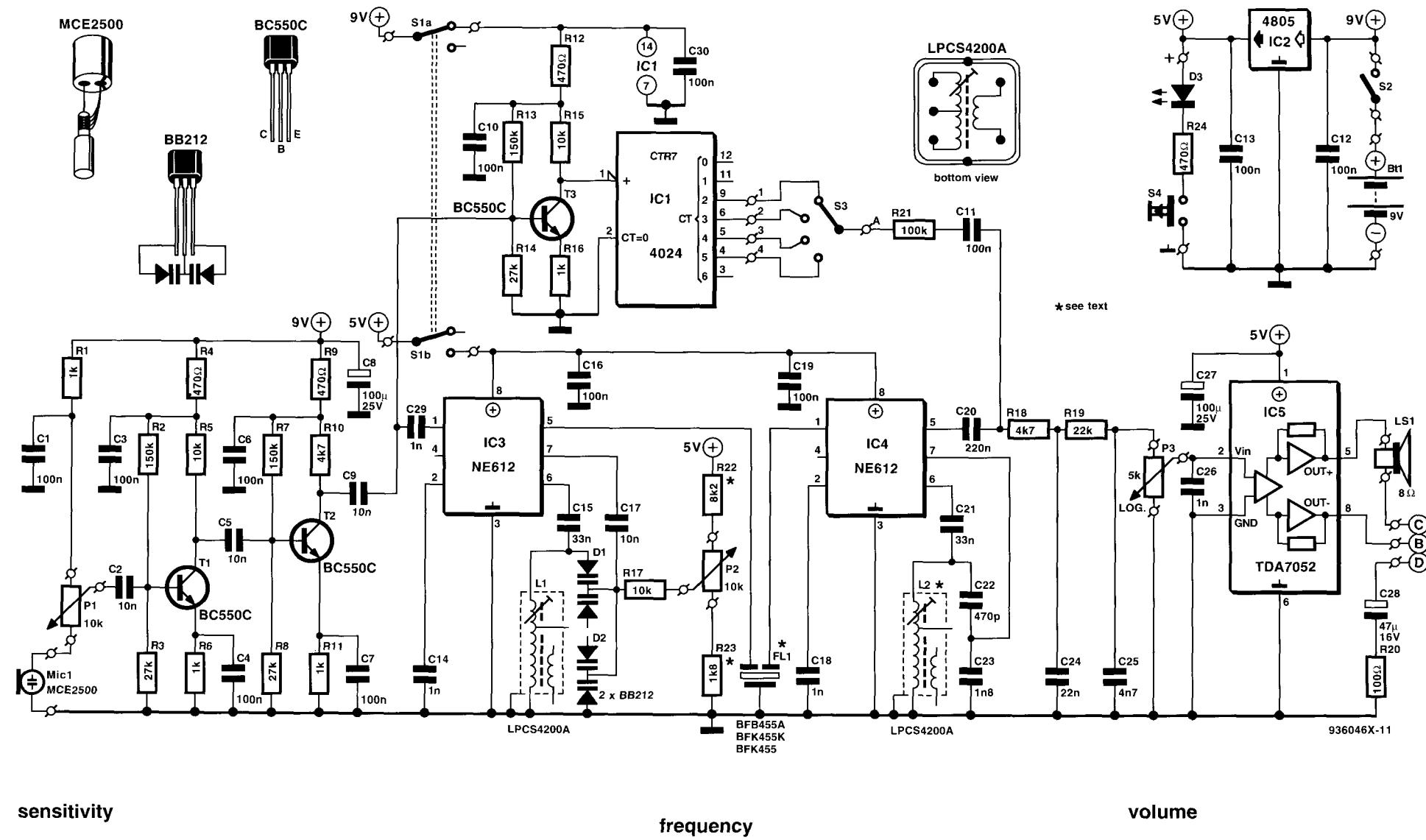


Fig. 1. Hearing range of man, some mammals and a few insects.



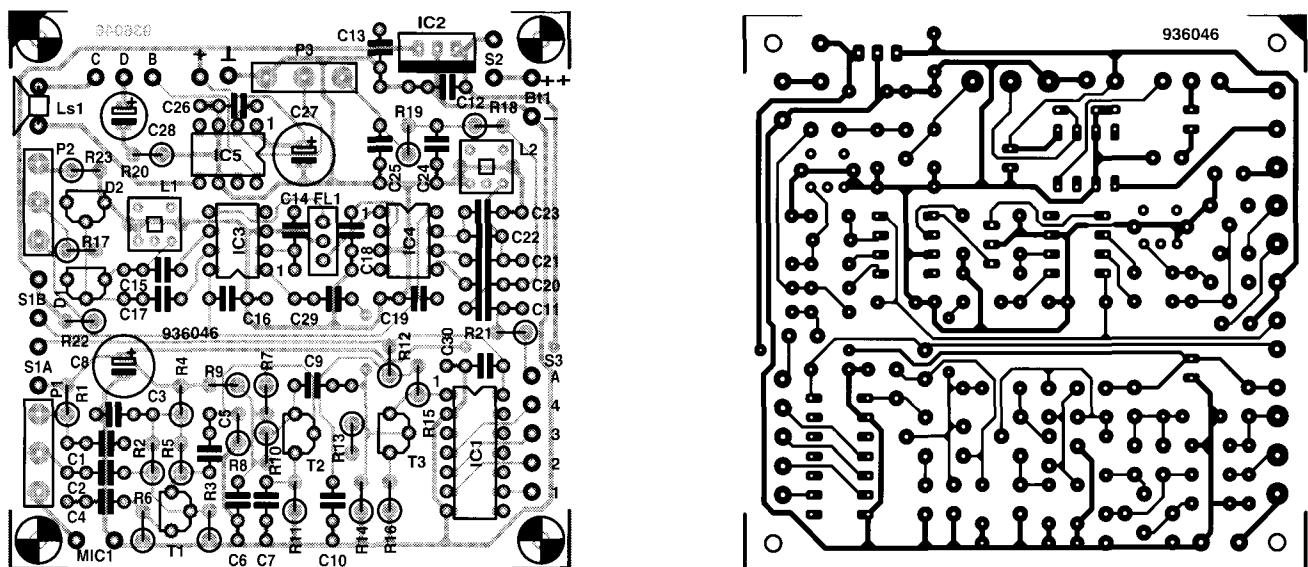


Fig. 3. Printed-circuit board for the bat detector.

and P_1 . The output of the microphone is applied to a two-stage preamplifier, T_1 and T_2 , via sensitivity control P_1 . The values of C_1 – C_7 and C_9 are small to ensure that frequencies below about 10 kHz (which are of no interest in the present application) are not magnified by the preamplifier. In other words, the preamplifier functions as an active high-pass filter, so that all frequencies in the wanted range are of about the same level.

As stated earlier, the detector provides two different means of converting ultrasonic sounds into audible ones: division and superheterodyning. Each has its own circuitry and the output of the preamplifier is, therefore, applied to two different sections in Fig. 2.

The section around T_3 and IC_1 is a frequency divider. The gain of T_3 (20 dB), determined by the ratio R_{15} : R_{16} , ensures that even with weak

inputs the signal at pin 1 of IC_1 is sufficient for the proper operation of the divider. At the same time, the gain is not so high that the circuit reacts to the ever-present ambient noise.

The frequencies of the signal applied to IC_1 are divided by a number of cascaded binary scalers. Although IC_1 has seven outputs, only those that give a scaling factor of 4, 8, 16 or 32 are used and selected with S_3 . For instance, with S_3 in position 4, an ultrasonic input of 32 kHz is divided by 32 and thus converted to a 1 kHz tone.

The output of IC_1 is applied to a.f. amplifier IC_5 via attenuator R_{21} .

The superheterodyne section is

based on IC_3 and IC_4 . In IC_3 , the output of T_2 is converted to a fixed intermediate frequency, i.e., of 455 kHz. This, in conjunction with bandpass filter FL_1 , makes it simple to extract the wanted signal from the spurious ones and noise.

To obtain a difference frequency of 455 kHz, the 10–300 kHz input signals are mixed with the output of a Colpitts oscillator that covers the frequency range of 465–755 kHz. Associated with the oscillator are inductor L_1 and varactors D_1 and D_2 . If, for instance, the incoming signal is 100 kHz, the oscillator in IC_3 must be tuned to 555 kHz to obtain a difference frequency of

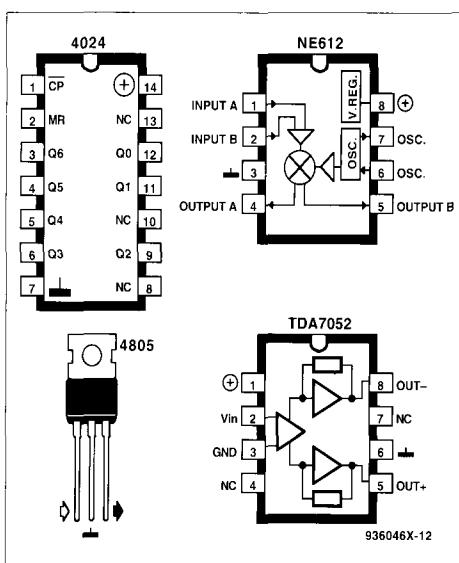


Fig. 4. Pinouts of the integrated circuits.

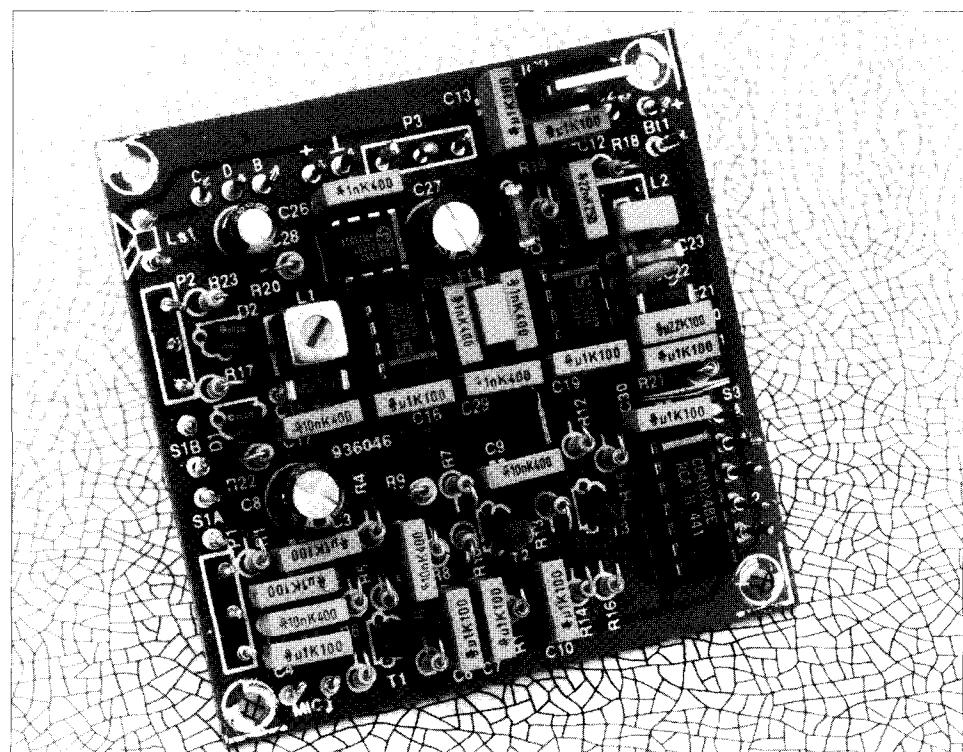


Fig. 5. Completed prototype printed-circuit board.

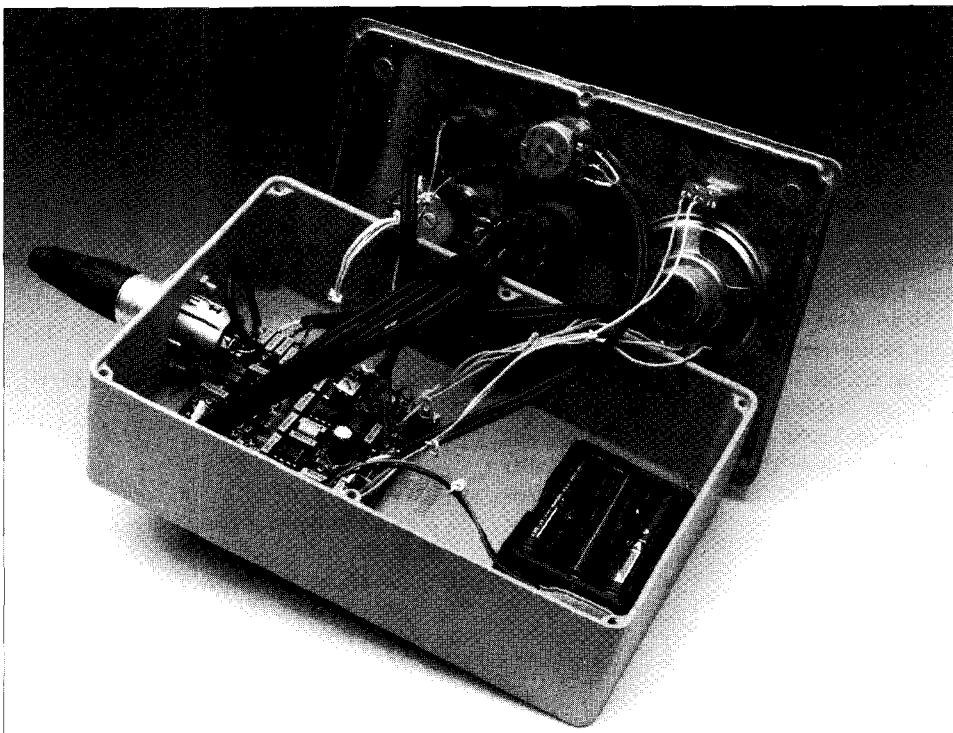


Fig. 6. completed prototype with top cover removed.

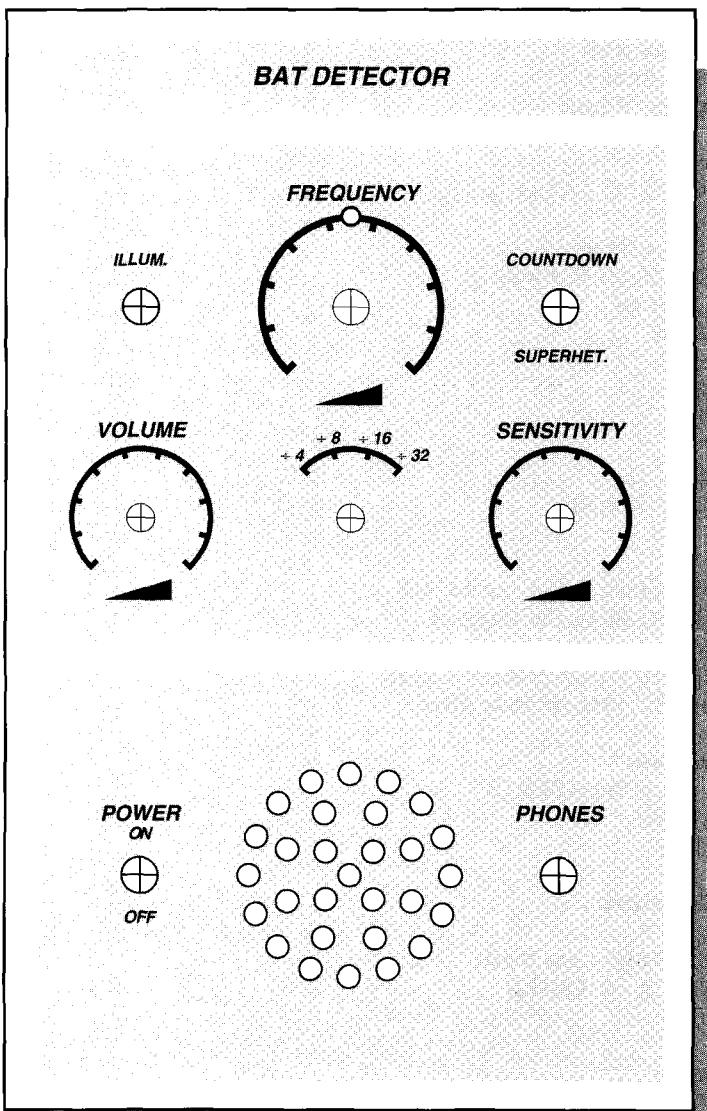


Fig. 7. Suggested front panel layout (scale 8:10).

455 kHz. The reason that of each of the two dual varactors only one half is used is that it enables constructors to use a lower inductance for L_1 . In that case, the oscillator frequency range lies somewhat higher; the second half of D_2 should then be connected in parallel with the other half to pull the range down again.

When the voltage across the varactors is a minimum, the capacitance is a maximum and the oscillator generates its lowest frequency (465 kHz). Turning P_2 to the position where the resistance between the wiper and junction $R_{22}-P_2$ is minimum, the oscillator generates its highest frequency (755 kHz).

Inductors L_1 and L_2 are 455 kHz i.f. transformers of which only the two outer windings are used. The integral parallel capacitor in both should be disabled by gently pushing a small screwdriver through its centre.

The 455 kHz signal is, of course, still not audible and it is, therefore, applied to a second mixer, IC_4 . The frequency of the oscillator in this stage is determined by $L_2-C_{22}-C_{23}$. This is tuned to 452 kHz or 458 kHz in order to produce a 3 kHz tone (normal human hearing is at its most sensitive at this frequency). In the prototype, a frequency of 452 kHz was preferred since this ensures that when the input frequency rises, the audio output also rises.

The 3 kHz signal at the output of IC_4 (pin 5) is applied to a.f. amplifier IC_5 via double low-pass filter $R_{18}-C_{24}$ and $R_{19}-C_{25}$. This filter also removes the higher harmonics from the rectangular output of the divider. Potentiometer P_3 is the volume control. The amplifier chip contains a driver stage and an output stage, which can drive a small loudspeaker or headphones.

Power for the detector is obtained from a 9 V (PP3 = 6F22) battery. The 5 V line is derived from this battery by regulator IC_2 . Although low-drop Type 4805 is preferred, a standard Type 7805 can be used, but the battery voltage should then not be allowed to drop below 8 V.

Switch S_1 serves to select 'division' or 'superheterodyne' operation.

Push-button switch S_4 serves to switch on D_3 which functions as pointer and illumination for the frequency scale around P_2 . The LED in the D_3 position (and its series resistor) may be replaced by a small bulb from an alarm clock.

Construction

The detector is preferably built on the printed-circuit board shown in **Fig. 3**. As usual, first mount the passive components, then the inductors and lastly the semiconductors and integrated circuits. It may be necessary when alter-

native types of inductor are used to drill out some of the relevant holes in the board. A photograph of the completed board is shown in **Fig. 5**.

The prototype detector is housed in a $188 \times 120 \times 57$ mm ($7\frac{3}{8} \times 4\frac{3}{4} \times 2\frac{1}{4}$ in) metal enclosure—see **Fig. 6**. As is seen, a somewhat smaller enclosure may do just as well.

The frequency scale in **Fig. 8** is intended to be glued around the hole for the frequency control. Note that this is just an example, since tolerances of the oscillator in IC_3 may make the positions slightly different. A calibrated scale is readily made with the aid of a frequency meter and/or signal generator.

The microphone may be mounted in a side of the enclosure or used as a separate entity connected to the detector by a length of screened audio cable.

Note that the jack socket for the headphones must be insulated from the enclosure by nylon washers and a nylon bush to prevent pins 5 and 8 of IC_5 being shorted to chassis.

Calibration

Connect the 9 V battery to the detector and switch on the supply with S_2 . Turn P_3 clockwise, when noise should become audible from the loudspeaker (or headphones). When S_1 is changed over, the noise level should increase or decrease (there is more noise when the superheterodyne section is on).

Set S_1 to COUNTDOWN and P_1 to maximum sensitivity. Rattle a set of keys in front of the microphone; this should produce a fairly loud noise in the loudspeaker.

With the detector near an operating TV receiver or computer monitor, a continuous whistle should be heard from the loudspeaker (try all positions of S_3). This is because the deflection coils or the line transformers in a TV receiver emit a continuous tone of 15 625 Hz; that of a computer monitor is normally somewhat higher.

If the divider works correctly, set S_1 to SUPERHET. If a 455 kHz i.f. transformer is used in the L_2 position, adjust the inductance with a frequency meter as described later for L_1 or by listening to the loudspeaker: when L_2 is adjusted, the noise increases and its tone changes from high to low and then to high again. The correct setting is at the low tone. If a 452 kHz ceramic resonator is used in the L_2 position, this adjustment is not necessary.

Turn P_2 to check whether the oscillator in IC_3 can be tuned to 455 kHz. At that point, a whistle going from high to low and then to high again becomes audible. In the prototype, this happened with P_2 completely anticlockwise and the core of L_1 almost at its top position. With P_2 completely clockwise,

the oscillator frequency was 755 kHz.

If these results can not be obtained, the oscillator frequency is almost certainly too high. This may be remedied by lowering the value of R_{23} (down to 0 Ω if need be). If this still does not give the desired result, a frequency meter should be used to determine at which frequency the oscillator does work and over what range it can be tuned.

Note that although the calibration may be carried out by ear, it is always better to do it with the aid of a frequency meter. Couple this meter loosely to L_1 or L_2 via a 10–100 pF capacitor. Adjust the core of the relevant inductor to obtain the correct frequency.

Parts list

Resistors:

$R_1, R_6, R_{11}, R_{16} = 1 \text{ k}\Omega$
 $R_2, R_7, R_{13} = 150 \text{ k}\Omega$
 $R_3, R_8, R_{14} = 27 \text{ k}\Omega$
 $R_4, R_9, R_{12}, R_{24} = 47 \text{ }\Omega$
 $R_5, R_{15}, R_{17} = 10 \text{ k}\Omega$
 $R_{10}, R_{18} = 4.7 \text{ k}\Omega$
 $R_{19} = 22 \text{ k}\Omega$
 $R_{20} = 100 \text{ }\Omega$
 $R_{21} = 100 \text{ k}\Omega$
 $R_{22} = 8.2 \text{ k}\Omega$
 $R_{23} = 1.8 \text{ k}\Omega$ (see text)
 $P_1, P_2 = 10 \text{ k}\Omega$, linear
 $P_3 = 4.7 \text{ k}\Omega$, logarithmic

Capacitors:

$C_1, C_3, C_4, C_6, C_7, C_{10}–C_{13}, C_{16}, C_{19}$,
 $C_{30} = 100 \text{ nF}$
 $C_2, C_5, C_9, C_{17} = 10 \text{ nF}$
 $C_8, C_{27} = 100 \text{ }\mu\text{F}$, 25 V, radial
 $C_{14}, C_{18}, C_{26} = 1 \text{ nF}$
 $C_{15}, C_{21} = 33 \text{ nF}$
 $C_{20} = 220 \text{ nF}$
 $C_{22} = 470 \text{ pF}$
 $C_{23} = 1.8 \text{ nF}$
 $C_{24} = 22 \text{ nF}$
 $C_{25} = 4.7 \text{ nF}$
 $C_{28} = 47 \text{ }\mu\text{F}$, 16 V, radial

Inductors:

Note: if i.f. transformers are used, see text about disabling the integral capacitor.
 $L_1 = \text{LPCS4200A/93309}$ (Toko = Cirkit)
 $L_2 = \text{as } L_1 \text{ or } 452 \text{ kHz ceramic filter.}$

Semiconductors:

$D_1, D_2 = \text{varactor Type BB212}$
 $D_3 = \text{LED, yellow}$
 $T_1–T_3 = \text{BC550C}$

Integrated circuits:

$IC_1 = 4024$
 $IC_2 = 4805$ (or 7805 - see text)
 $IC_3, IC_4 = \text{NE612}$ (or NE602)
 $IC_5 = \text{TDA7052}$

Miscellaneous:

$S_1 = \text{double-pole change-over switch}$
 $S_2 = \text{single-pole on/off switch}$
 $S_3 = \text{single-pole, four-position (rotary)}$

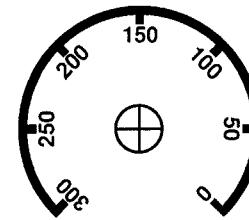


Fig. 8. Suggested frequency scale for P_2 .

switch

S_4 = push-button switch with make contact

Mic_1 = electret microphone

Fl_1 = 455 kHz i.f. filter

Ls_1 = loudspeaker, 8–16 Ω , 200 mW

K_1 = jack socket with break contact

Enclosure 188×120×57 mm

($7\frac{3}{8} \times 4\frac{3}{4} \times 2\frac{1}{4}$ in) metal

Bt_1 = 9 V battery with clip

PCB Order No. 936046

[936046]